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ScienceDirect

Energy Procedia 99 (2016) 108 – 119

Energy Procedia

10th International Renewable Energy Storage Conference, IRES 2016, 15-17 March 2016, Düsseldorf, Germany

What is stored, why, and how? Mental models, knowledge, and public acceptance of hydrogen storage

Barbara S. Zaunbrecher[a]*, Thomas Bexten[b], Manfred Wirsum[b], Martina Ziefle[a]

[a]*Chair and Institute of Communication Science, Human-Computer Interaction Center, RWTH Aachen University, 52056 Aachen, Germany*
[b]*Chair and Institute of Power Plant Technology, Steam and Gas Turbines, RWTH Aachen University, 52056 Aachen, Germany*

Abstract

Although electricity storage plays a decisive role for the German "Energiewende," and it has become evident that the successful diffusion of technologies is not only a question of technical feasibility but also of social acceptance, research on electricity storage technologies from a social science point of view is still scarce. This study, therefore, empirically explores laypersons' mindsets and knowledge related to storage technologies, focusing on hydrogen. While the results indicate overall supportive attitudes and trust in hydrogen storage, some misconceptions, a lack of information as well as concerns were identified which should be addressed in future communication concepts.

Peer-review under responsibility of EUROSOLAR - The European Association for Renewable Energy

Keywords: power storage; electricity supply; renewable energy; public attitude; laypersons; technology acceptance; survey; interview

1. Introduction

The energy transition towards a higher share of renewables is currently a hot topic, not only in research and development but also in the public discussion. One of the reasons for this might be the infrastructure-related features that make the energy turn visible in the landscape: wind turbines, solar panels, or new transmission lines. Those infrastructure changes modify the landscape people are used to live in into an "energy landscape" [1]. This does not go without protest, as the foundation of numerous citizen initiatives shows (e.g.,[2,3]). In this context, it has been

* Barbara Sophie Zaunbrecher. Tel.: +49-241-80-49221.
E-mail address: zaunbrecher@comm.rwth-aachen.de

Peer-review under responsibility of EUROSOLAR - The European Association for Renewable Energy
doi:10.1016/j.egypro.2016.10.102

shown that not all infrastructure development is associated with the energy transition to the same extent. While it is fairly obvious that new wind turbines are connected to the energy transition, this is less so for new transmission lines [4]. Similarly, storage technologies, which will play an essential role in future grids with volatile energy production based on, e.g., wind and solar power, have not yet received much attention in the public discourse. While social acceptance for power producing infrastructure like wind turbines or biomass plants has increasingly gained importance in research and development, the social acceptance of storage technology for electricity has been neglected so far. Components of the electricity grid, however, will increasingly penetrate our living environments in the foreseeable future. Therefore, it will be important to understand people's attitudes towards different types of electricity storage facilities in order to avoid local opposition with the risk of severely delaying extension of necessary infrastructure and to meet public concerns adequately with a sensibly tailored information and communication strategy.

Hydrogen is one possibility to store electricity. It is already used in the context of mobility and studies show that it is increasingly accepted [5]. It might be hypothesized, though, that people's attitudes and public perception are quite different when hydrogen is used in large-scale applications for storage, within urban environments, near city quarters, or even close to people's homes. In this context, it is also a relevant issue if public perceptions differ between different types of storage technologies (e.g., battery, flywheel generator, etc.), and how hydrogen is perceived relative to these other storage possibilities.

One major driver for the social acceptance of a novel technology is the appropriateness of people's explicit and implicit knowledge about a technology, often referred to as so-called mental models [6]. Mental models cover persons' attitudes, cognitive and affective conceptions and beliefs how a technology might work, the characteristics that are associated with it as well as possible consequences regarding implementation procedures or personal use. Mental models are not necessarily intentional and cognizant, but they work as affective, hidden drivers for the attitude for or against a technology [7]. Mental models are formed by experience and therefore often contain incomplete or even "wrong" conceptions. Uncovering mental models as drivers for acceptance is thus essential for the development of communication strategies that can be individually tailored to the specific information needs, public misconceptions, or fears [8].

In order to understand those mental models in the context of hydrogen storage in large-scale technologies an exploratory study had been conducted adopting a twofold approach, combining qualitative and quantitative methods: first, interviews are conducted with a range of laypeople to explore mental models about hydrogen storage. Second, a quantitative study is conducted in which knowledge about hydrogen storage, its perception, and its acceptance are evaluated.

2. Hydrogen storage in the context of the energy transition ("Energiewende")

The German "energy transition" and similar policies in other European countries result in a continuously increasing share of renewable power generation in the total European power generation mix. Most renewable power generation technologies are characterized by high volatility and low predictability of the power output which poses various challenges for a stable and reliable operation of the electricity grid [9]. One option to cope with these challenges is the utilization of energy storage technologies. Due to the limited geographical potential for large-scale storage plants (e.g., pumped storage, compressed air energy storage) the use of distributed mid- and small-scale energy storage systems is likely to increase in the future [10]. Examples for these distributed storage systems are batteries, flywheels, and hydrogen storage systems. While flywheels and batteries are mainly used for short-term storage, the conversion of excess electricity into hydrogen via electrolysis represents a possibility for intermediate and long-term storage. There are various technologies to subsequently store the produced hydrogen. An effective option is the direct feed-in into the natural gas grid which functions as the storage system in this case. This option, however, is limited due to the technical limitation of the hydrogen fraction in natural gas [11]. Another option is the conversion of the hydrogen to methane in a subsequent chemical process using carbon dioxide. This additional conversion allows for an unlimited feed-in of the methane into the natural gas grid, but it is also associated with significant additional conversion losses [12]. The third option is the direct storage of hydrogen in local storage systems. These include pressurized tanks, combinations of liquidation units and unpressurized tanks, and innovative storage technologies like metal hydrides [13]. Due to the high complexity of liquidation units and the status of the